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ORIGINAL ARTICLE

Malnutrition in critically ill children: from admission to 6 months after discharge ☆

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Summary *Background & Aims*: Little is known about the nutritional status of critically ill children during hospitalisation in and after discharge from an intensive care unit. We set up a prospective, observational study to evaluate the nutritional status of children in an intensive care unit from admission up to 6 months after discharge. A secondary aim was identifying patient characteristics that influence the course of the various anthropometric parameters.

Methods: The nutritional status of 293 children—104 preterm neonates, 96 term neonates and 93 older children—admitted to our multidisciplinary tertiary pediatric and neonatal intensive care unit was evaluated by anthropometry upon and during admission, at discharge and 6 weeks and 6 months following discharge.

Results: Upon admission, 24% of all children appeared to be undernourished. Preterm and term neonates, but not older children, showed a decline in nutritional status during admission. At 6 months after discharge almost all children showed complete recovery of nutritional status. Length of stay and history of disease were the parameters that most adversely affected the nutritional status of preterm and term neonates at discharge and during follow-up.

Conclusion: While malnutrition is a major problem in pediatric intensive care units, most children have good long-term outcome in terms of nutritional status after discharge.

Introduction

Critical illness has a major impact on the nutritional status of both children and adults. Studies conducted more than 20 years ago already demonstrated that 15–20% of children admitted to pediatric intensive care units were acutely or chronically malnourished.[1–4] Recent data on the prevalence of malnutrition in pediatric intensive care units are not available. It is not unimaginable, however, that this prevalence has changed, on account of improved intensive care technology, lowering of the age at which major surgery is performed and increased awareness of the significance of adequate nutritional support.

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While follow-up studies concerning nutritional status in premature neonates are available,[5–7] the nutritional status of critically ill children after discharge from an intensive care unit (ICU) has not been documented. The available follow-up studies focus on mortality and functional outcome,[8,9] rather than on nutritional status. Studies in specific subsets of patients, e.g. those with severe burns,[10,11] reveal impaired growth for up to 2 years.

The protein-energy malnutrition that may develop during ICU-stay is associated with an increase in morbidity and mortality,[3,12] whereas malnutrition in infancy is associated with poor growth and reduced or delayed mental and psychomotor development.[5,13–15] Recent studies in critically ill children showed a wide variation in individual energy expenditure.[16,17] This phenomenon would make them more vulnerable for energy malnutrition, seeing that a standard feeding protocol fails to take inter-individual differences into account. Moreover, individual assessment of a patient's nutritional status as guidance for nutritional support is not part of the routine procedures upon admission to a pediatric ICU. Because none of the available methods—including weight measurements, biochemical parameters, and dual-energy X-ray absorptiometry (DEXA)—is free from pitfalls, there is no single best test for nutritional assessment in ICU patients. Newly introduced non-invasive techniques, such as bioelectrical impedance analysis (BIA) and DEXA, have shown to be difficult in practice and very demanding, and most have not been validated for critically ill children, notably the very young.[18,19] Furthermore, in the acute setting hormonal and biochemical nutritional assessment parameters are predominantly useful as markers of disease severity and not of nutritional status per se.[20] This leaves anthropometry as the best tool currently available for assessing the nutritional status of a heterogeneous group of critically ill children, the more so because recent reference values are available for the different age groups and sexes.[21]

We conducted a prospective observational study to determine the nutritional status of a cohort of critically ill children by means of anthropometric parameters from admission to 6 months after discharge from a tertiary intensive care unit. Furthermore, we set out to identify risk factors for poor nutritional status at admission and during follow-up.

Materials and methods

Children admitted during the year 2001 to our level III multidisciplinary neonatal and pediatric\surgical intensive care unit (ICU) with an expected stay of at least 48 h were included in the study, provided written parental informed consent had been obtained. Exclusion criteria were withholding or withdrawing of treatment, inclusion into another nutritional intervention study, and treatment with Extra Corporeal Membrane Oxygenation (ECMO). Most patients on ECMO develop extreme generalised oedema, and consequently their anthropometric measurements are unreliable. The institutional review board of Erasmus MC approved the study protocol.

We recorded the patients' sex, age, surgical status, pre-existent health status, severity of illness, duration of mechanical ventilation and length of stay at the ICU (LOS). The patients were classified by age into three age groups in order to differentiate between growth patterns: preterm neonates (gestational age <37 weeks; post-conceptual age $\leqslant 40$ weeks), term neonates (0–30 days) and older children (>30 days). Patients were also classified by diagnosis into seven categories (Table 1). Pre-existent health status was defined as either 'previously healthy with normal growth' or 'history of growth-affecting disease' (e.g. congenital anomaly, chromosomal abnormalities, dysmaturity or chronic systemic disease).

Severity of illness was measured at admission by either of two validated scores: the Pediatric Risk of Mortality score (PRISM) for the term neonates and older children (score range 0–76);[22] the Clinical Risk Index for Babies (CRIB) for the preterm neonates (score range 0–23).[23] All infants were enterally and/or parenterally fed according to the current feeding protocol.

Within 24 h after admission anthropometric measurements were performed including weight, length, head circumference (HC), mid upper arm circumference (MUAC), calf circumference (CC) and the skinfold thicknesses of biceps (BSF) and triceps (TSF). These measurements (except head circumference and length) were repeated every other day during the first 2 weeks and weekly thereafter. A reassessment was performed at discharge for most anthropometric parameters. Length and head circumference were measured at discharge in a selected group consisting of children less than 2 years of age with LOS of at least 12 and 6 days, respectively. When a child's reassessment on the day of discharge was not possible, the previous measurements taken closest to discharge were used, provided the period between this day and discharge was within 20% of the total duration of stay. Otherwise, the measurements were considered to be missing. Full anthropometric evaluation was repeated at 6 weeks and 6 months after discharge from the ICU.

Table 1 Patient characteristics and diagnoses ($n = 293$).

Patient characteristics		
M:F	*N* (%)	167:126 (57:43)
Age	Median (range), days	2 (0 days–17 years)
Age groups		
Preterm neonates	*N* (%)	104 (35%)
Gestational age	Mean (SD), weeks	31.4 (2.7)
Postconceptual age	Mean (SD), weeks	31.9 (2.9)
Term neonates	*N* (%)	96 (33%)
Gestational age	Mean (SD), weeks	39.4 (1.5)
Postnatal age	Median (range), days	1 (0–30)
Older children	*N* (%)	93 (32%)
Age	Median (range), years	1.4 (31 days–17 years)
PRISM ($n = 189$)	Median (range)	11 (0–38)
CRIB ($n = 76$)	Median (range)	3 (0–16)
Length of stay	Median (range), days	7 (2–314)
Mechanical ventilation	*N* (%)	211 (72)
Duration	Median (range), days	3 (0–53)
History of growth-affecting disease	*N* (%)	123 (42)
Surgery	*N* (%)	92 (31)
Diagnostic groups		
Prematurity/dysmaturity	*N* (%)	84 (29)
Congenital annomalies	*N* (%)	65 (22)
Post-operative monitoring	*N* (%)	44 (15)
Respiratory illness*	*N* (%)	41 (14)
Postnatal problems†	*N* (%)	24 (8)
Sepsis or meningitis	*N* (%)	22 (8)
Other	*N* (%)	13 (4)

CRIB = Clinical Risk Index for Babies; PRISM = Pediatric Risk of Mortality.
*Includes pneumonia, RS-bronchiolitis.
†Includes asphyxia, meconium aspiration, infection.

Body weight, without diapers and clothes, was measured to the nearest 0.01 kg in a standardised way using calibrated scales. Length was obtained to the nearest 0.1 cm by measuring crown-heel length in the supine child. During the follow-up visits, standing height was measured by a stadiometer in the children who were able to stand. HC was measured with a tape around the head at the most protruding points of the occiput and forehead. TSF and BSF served to establish subcutaneous fat stores, and were measured to the nearest 0.1 cm with a Harpenden skin fold caliper (UK), using the mean of three separate readings.[24]. The caliper was applied while keeping the skinfold between thumb and forefinger, and had to remain in position until the measurement had stabilised (2–5 s). Neonates with body weight <1000 g were excluded from skin fold measurements. MUAC and CC were measured to the nearest 0.1 cm.

Intra- and inter-observer studies performed prior to the study had shown good reproducibility of measurements with coefficients of variation $<3\%$ for MUAC and CC, and $<7\%$ for BSF and TSF.

All anthropometric data were compared with recently published standards based on a Dutch reference population and transformed into standard deviation scores (SD-scores) by means of a software program (TNO, Prevention and Health, Leiden, the Netherlands).[21] Acute malnutrition was defined as a standard deviation score (SDS) for weight-for-age (WFA-SDS) of more than 2 below the mean. Chronic malnutrition was defined as a SDS for length-for-age (LFA-SDS) of more than 2 below the mean. SD-scores of CC and MUAC more than 2 below the mean are associated with inadequate protein stores and acute malnutrition whereas a SDS of TSF <-2 is associated with deficient fat stores and chronic malnutrition.[25] Children with a decrease in SDS between admission and discharge of >1 SD were included in the analyses as well.

In neonates up to a post-conceptual age of 41 weeks the calculation of SD-scores for weight, length and head circumference was based on the intra-uterine growth curves of Usher and McLean.[26] SD-scores for weight, length and head circumference for older children were derived from the

recently published standards of a Dutch population study in 1997.[21] The individual measurements of MUAC, CC, TSF and BSF of all children starting from term age were compared with normative data of a Dutch reference population and also expressed in SD-scores in children.[27] The ages of prematurely born children with postnatal age <2 years were corrected for prematurity.

Statistical analyses

The Statistical Package for Social Sciences (version 10.0, SPSS Inc., Chicago, IL) was used for statistical analyses. Longitudinal analysis of the growth data, including the comparison of mean values, allowing for missing data, was performed using repeated measures analysis of variance (PROC MIXED, SAS, Cary, NC) on the three subsets based upon age.

Clinical factors suspected to influence the changes in SD-scores were analysed in order to determine the major factors related to outcome. The dependent variables were the SD-scores at discharge, 6 weeks after discharge and 6 months after discharge for WFA and LFA. Variables initially tested for association in univariate regression analysis included age, gender, severity of illness (PRISM or CRIB), length of stay at the ICU, duration of ventilation, having undergone surgery, and previous health status. All analyses were adjusted for the SDS at admission. Variables associated with the dependent variable in the univariate analysis ($P<0.05$) were entered in a stepwise linear regression with backward elimination. Paired percentages were compared using the McNemar test. We considered $P<0.05$ to be significant.

Results

Subjects

A total of 342 children were enrolled in the study. For various reasons 49 of them were not included in the analyses (Fig. 1). The characteristics and diagnoses of the remaining 293 children are shown in Table 1.

The first and second follow-up measurements actually took place after a mean (SD) of 6.3 ± 1.8 and 26.6 ± 3.3 weeks after discharge, respectively. We collected data of 268 (91%) children at first follow up and 260 (89%) children at second follow up.

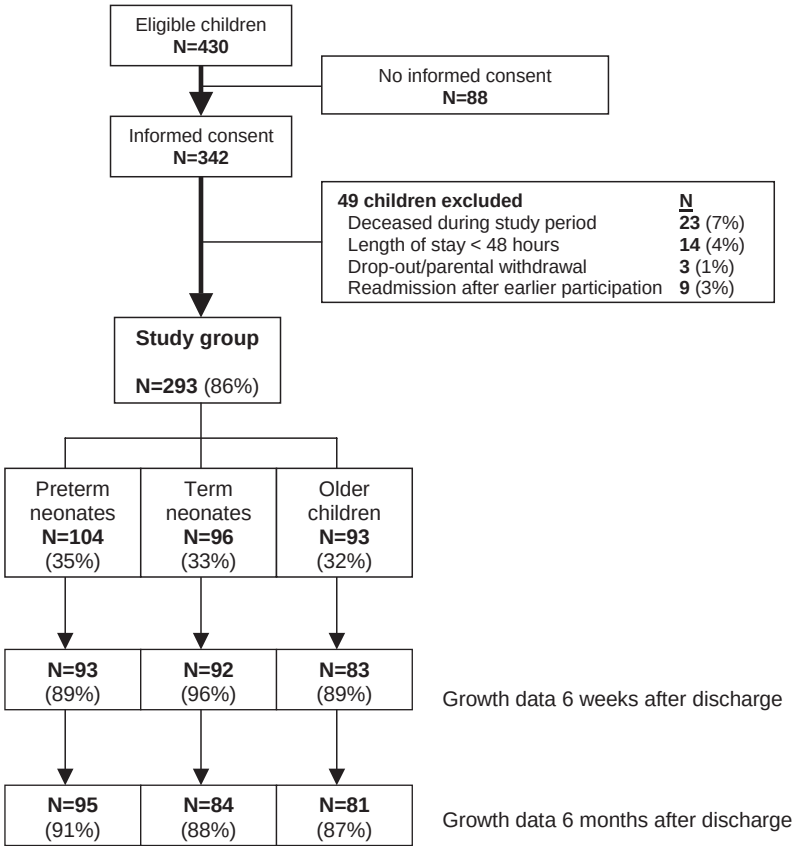

Figure 1 Flow chart of the study population.

Table 2 Standard deviation scores (SDS) of the different growth parameters upon admission, at discharge and 6 weeks and 6 months after discharge for the 3 different age groups.

Growth parameter (SDS)	Admission	Discharge	6 Weeks after discharge	6 Months after discharge
Preterm neonates ($n=104$)				
WFA	-0.52 ± 0.15	$-1.44\pm0.15^{\ddagger}$	$-1.39\pm0.15^{\ddagger}$	$-0.60\pm0.15^{\S,\P}$
LFA	-1.31 ± 0.17	$-2.72\pm0.28^{\ddagger}$	$-1.66\pm0.17^{\ddagger}$	$-0.39\pm0.14^{\ddagger,\P}$
LFA ($n=52$)*	*-1.69 ± 0.28*	*$-2.72\pm0.28^{\ddagger}$*	*$-2.16\pm0.26^{\S}$*	*$-0.90\pm0.20^{\ddagger,\S,\P}$*
HC	-0.19 ± 0.12	—	-0.27 ± 0.13	$0.12\pm0.13^{\ddagger,\P}$
HC† ($n=72$)	*-0.37 ± 0.15*	*$-1.22\pm0.17^{\ddagger}$*	*$-0.43\pm0.16^{\S}$*	*$-0.02\pm0.15^{\ddagger,\S,\P}$*
MUAC	—	—	-2.41 ± 0.14	$-0.26\pm0.13^{\P}$
CC	—	—	-2.17 ± 0.13	$0.26\pm0.16^{\P}$
TSF	—	—	-1.93 ± 0.08	$-1.00\pm0.08^{\P}$
BSF	—	—	-1.30 ± 0.09	$-0.50\pm0.08^{\P}$
Term neonates ($n=96$)				
WFA	-0.30 ± 0.13	$-0.97\pm0.15^{\ddagger}$	*$-0.76\pm0.12^{\ddagger}$*	$-0.65\pm0.11^{\ddagger,\S}$
LFA	-0.28 ± 0.13	—	-0.50 ± 0.13	$-0.23\pm0.12^{\P}$
LFA ($n=23$)*	*0.20 ± 0.24*	*$-0.91\pm0.25^{\ddagger}$*	*$-0.76\pm0.18^{\ddagger}$*	*$-0.19\pm0.23^{\S,\P}$*
HC	-0.01 ± 0.14	—	$-0.28\pm0.13^{\ddagger}$	$-0.28\pm0.11^{\ddagger}$
HC† ($n=53$)	*0.02 ± 0.20*	*$-0.53\pm0.17^{\ddagger}$*	*$-0.34\pm0.18^{\ddagger}$*	*-0.25 ± 0.15*
MUAC	-2.26 ± 0.01	-2.25 ± 0.01	$-1.68\pm0.11^{\ddagger,\S}$	$0.06\pm0.12^{\ddagger,\S,\P}$
CC	-2.68 ± 0.11	-2.68 ± 0.10	$-1.49\pm0.11^{\ddagger,\S}$	$0.45\pm0.12^{\ddagger,\S,\P}$
TSF	-2.10 ± 0.05	-2.10 ± 0.05	$-1.65\pm0.06^{\ddagger,\S}$	$-1.07\pm0.10^{\ddagger,\S,\P}$
BSF	-1.38 ± 0.05	-1.37 ± 0.04	$-1.08\pm0.06^{\ddagger,\S}$	$-0.39\pm0.09^{\ddagger,\S,\P}$
Older children ($n=93$)				
WFA	-0.94 ± 0.19	-0.92 ± 0.20	-0.82 ± 0.17	$-0.50\pm0.15^{\ddagger,\S,\P}$
LFA	-0.79 ± 0.21	—	-0.89 ± 0.18	$-0.64\pm0.15^{\P}$
LFA ($n=13$)*	*-0.68 ± 0.43*	*-0.42 ± 0.43*	*$-1.08\pm0.30^{\S}$*	*-0.90 ± 0.32*
HC	-0.24 ± 0.16	—	$-0.41\pm0.14^{\ddagger}$	$-0.17\pm0.14^{\P}$
HC† ($n=32$)	*-0.83 ± 0.32*	*-0.92 ± 0.32*	*-1.02 ± 0.26*	*-0.76 ± 0.25*
MUAC	-0.28 ± 0.21	$-0.54\pm0.21^{\ddagger}$	-0.33 ± 0.19	$0.27\pm0.20^{\ddagger,\S,\P}$
CC	-0.76 ± 0.17	$-0.95\pm0.17^{\ddagger}$	$-0.45\pm0.17^{\ddagger,\S}$	$0.02\pm0.17^{\ddagger,\S,\P}$
TSF	-0.62 ± 0.16	$-0.89\pm0.14^{\ddagger}$	$-0.50\pm0.17^{\S}$	$-0.34\pm0.16^{\S}$
BSF	-0.34 ± 0.13	-0.39 ± 0.12	$-0.16\pm0.14^{\S}$	-0.15 ± 0.16

All values expressed as mean$\pm$SEM; WFA = weight-for-age, LFA = length-for-age, HC = head circumference, CC = calf circumference, MUAC = mid upper arm circumference, TSF = triceps skinfold, BSF = biceps skinfold.
*Only children with LOS $\geqslant$12 days and age $<$2 years.
†Only children with length of stay $\geqslant$6 days and age $<$2 years.
‡Value is significantly different when compared to admission, $P<0.05$.
§Value is significantly different when compared to discharge, $P<0.05$.
¶Value is significantly different when compared to 6 weeks after discharge, $P<0.05$.

Table 2 shows the SD-scores of all parameters upon admission, discharge and follow up. The course of the WFA-SDS over time is shown in Figure 2.

Nutritional status upon admission

The mean SD-scores of all anthropometric parameters of the three age groups upon admission, except length in the term neonates and head circumference in all children, were significantly below zero ($P<0.001$). In 15% of the children a WFA-SDS <-2 was found indicating acute malnutrition (14% of the preterm, 9% of the term neonates and 24% of the older children). In 84% of these children a history of growth-affecting disease was identified. In 20% of the children a LFA-SDS <-2 SD was found indicating chronic malnutrition (26% of the preterm, 11% of the term and 22% of the older children). Overall, 24% of the children showed signs of acute and/or chronic malnutrition

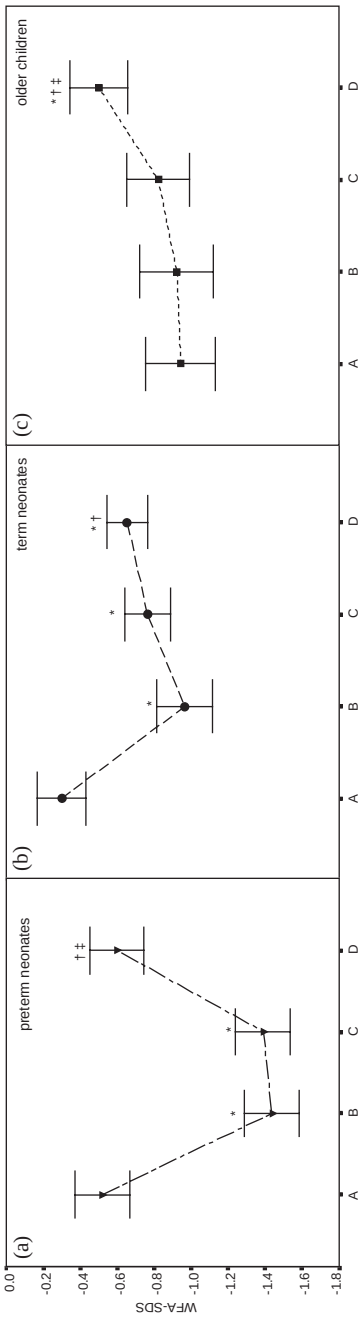

Figure 2 Standard deviation scores for weight-for-age upon admission, at discharge and 6 weeks and 6 months after discharge from the ICU for the 3 age groups: (a) preterm neonates, (b) term neonates, (c) older children. All values expressed as mean ± SEM. WFA-SDS = SD-score for weight-for-age: (A) admission, (B) discharge, (C) 6 weeks after discharge, (D) 6 months after discharge. *Value is significantly different when compared to admission, $P<0.05$; †value is significantly different when compared to discharge, $P<0.05$; ‡value is significantly different when compared to 6 weeks after discharge, $P<0.05$.

upon admission. Furthermore, 81%, 65% and 67% of term neonates had a score <-2 for CC-SDS, MUAC-SDS, and TSF-SDS, respectively. Percentages for the older children were 20%, 15% and 10%, respectively.

Nutritional status at discharge

Preterm neonates

Preterm neonates showed a significant decrease in mean WFA-SDS (Fig. 2a) (–0.92 SD, $P<0.001$) from admission to discharge. The proportion of preterm neonates classified as acutely malnourished had increased significantly at discharge (14 to 32%, $P<0.001$), of which 55% were new cases. In 44% of the preterm infants a more than 1 SD drop in WFA was observed between admission and discharge.

Also the mean LFA-SDS-score (–1.03 SD, $P<0.001$) and mean HC-SDS (–0.85 SD, $P<0.001$) decreased significantly. The proportion of children with a LFA-SDS <-2 increased significantly to 63% ($P=0.013$).

Term neonates

Term neonates showed a significant decrease in mean WFA-SDS (Fig. 2b) (–0.67 SD, $P<0.001$) from admission to discharge. The proportion of term neonates classified as acutely malnourished had increased significantly at discharge (9 to 23%, $P<0.001$), of which 62% were new cases. In 28% of the term infants a more than 1 SD drop in WFA was observed between admission and discharge. The mean LFA-SDS-score (–1.11 SD, $P<0.001$) and HC-SDS (–0.54 SD, $P<0.001$) also decreased from admission to discharge in the selected groups. The proportion of children with a LFA-SDS <-2 was comparable (16%) with that upon admission. SD-scores for CC, MUAC, TSF and BSF remained low during ICU-hospitalisation. The proportions of children with a CC-, MUAC-, or TSF-SDS <-2 did not change significantly (78%, 63% and 66%, respectively).

Older children

The mean WFA-SDS (Fig. 2c), LFA-SDS and HC-SDS were not significantly affected during IC-stay. The proportions of children classified as acutely (22%) or chronically (11%) malnourished upon discharge did not significantly differ from those upon admission. Only 4% of the older children dropped >1 SD in WFA between admission and discharge. The SD-scores for CC, MUAC and TSF showed a small but significant decline during the ICU-stay. The proportions of children with a CC-, MUAC-, or TSF-SDS <-2 did not significantly change (32%, 20% and 16%, respectively).

Nutritional status following discharge

Preterm neonates

Mean SD-scores of LFA and HC, but not WFA, increased significantly from discharge to 6 weeks after discharge (Table 2). At 6 months after discharge the mean outcomes of all parameters were either not different from or higher than those upon admission.

At 6 months after discharge 15% of the preterm neonates were acutely malnourished, which compares to the proportion upon admission. Thirteen percent had a LFA <-2, which was a significantly lower proportion ($P=0.021$) than that upon admission (26%).

Term neonates

Most SD-scores improved significantly from discharge to 6 weeks after discharge (Table 2). At 6 months after discharge the mean SD-scores for WFA (Fig. 2b) and HC had not yet been restored to the admission scores ($P=0.01$ and 0.025, respectively).

At 6 months after discharge the percentage of children classified as acutely malnourished was 12%, which compares to the proportion upon admission. Only 2% had a LFA-SDS <-2, which was a significantly lower proportion ($P=0.008$) than that upon admission (11%).

Older children

SD-scores of WFA, CC and MUAC at 6 months after discharge were significantly higher than those upon admission. All other SD-scores did not significantly differ from those upon admission (Table 2).

At 6 months after discharge 10% of children were classified as acutely malnourished which was significantly ($P=0.008$) lower than that upon admission. Thirteen percent had a LFA <-2, which was significantly ($P=0.031$) lower than the proportion upon admission (22%).

Effect of various factors on nutritional status

Severity of illness, age and sex were not found to have a significant influence on the course of the WFA- and LFA-SDS over time in all age groups.

In the preterm neonates a longer LOS was significantly related to a decrease in WFA-SDS at discharge (each doubling of LOS was associated with a decrease of –0.24 SD between admission and discharge). Both longer LOS and surgery negatively influenced the WFA and LFA-SDS during follow up. Preterm neonates with a WFA-SDS <-2 (SGA) upon admission showed a smaller decline in SDS between admission and discharge than children with a SD-score in the normal range did (–0.43 vs. –1.0 SD, respectively, $P=0.003$).

In term neonates LOS, gestational age and previous health status upon admission were significantly related to WFA-SDS at 6 weeks after discharge. In children with a history of disease, however, LOS had no additional negative effect upon the effect of their previous health status on the WFA-SDS at 6 weeks after discharge. At 6 months after discharge, LOS and previous health status negatively influenced the WFA-SDS. However, LOS had impact in the previously healthy population only. In the children with a history of growth-affecting disease no additional negative effect of LOS was observed. The LFA-SDS at 6 weeks after discharge was related to gestational age with a positive effect of 0.24 SD/week of gestational age. At 6 months after discharge LFA-SDS was negatively related to the LOS.

Older children who underwent a surgical intervention during admission had a mean WFA-SDS at 6 weeks after discharge that was 0.30 SD lower than that in the children without surgery.

Discussion

This study aimed at evaluating how admission to a specialised intensive care unit affects children's nutritional status during hospitalisation and up to 6 months after discharge. It yielded some remarkable findings on the prevalence of malnutrition upon admission and follow-up, and on the risk factors as well. The novelty of this study lies in starting nutritional assessment measurements as early as in the acute phase of the critical illness. While several studies have been performed in small, selected groups in the acute phase, such as in burn patients, most studies focussed on nutritional assessment starting in the recovery period or after the ICU-stay.[28–30]

Our primary observation is that critically ill children admitted to the ICU are in a poorer nutritional status than the general population. Overall, 24% of the children were acutely and/or chronically undernourished. The period of illness prior to the admission and/or the high prevalence of underlying disease in these children (84%) could explain this high proportion. It may also be speculated that being malnourished increases the chance of being admitted to an ICU as a consequence of disease. The proportion of malnourished children in our study population compares to findings from Pollack et al.[1–3] in the 1980s, which would seem to indicate that the problem of

malnutrition at pediatric intensive units has not improved at all.

Secondly, we found that at discharge, on average for the preterm and term neonates together, acute and chronic malnutrition rates had increased to 26% and 48%, respectively, whereas the prevalence of malnutrition in the older children was found not to have changed during the ICU-stay. Moreover, in 30% of all children the WFA-SDS had dropped >1 SD between admission and discharge, indicating acute malnutrition. In the older children the decline of SD-scores for mid upper arm circumference and skinfolds represented a diminished protein and fat condition. These measurements could provide a useful tool for assessing nutritional status during ICU-stay in this group of children.

Our third observation is very important in that almost all children showed complete recovery of their nutritional status within 6 months after discharge. Interestingly, most parameters were even higher than upon admission, with the exception of WFA in term infants. The complete recovery of nutritional status is surprising in view of findings from the few studies performed in subgroups of critically ill pediatric patients. Children with severe burns showed long term negative effects on nutritional status i.e. an exaggeration of hypermetabolism and catabolism for at least 9 months after injury, a decline in lean body mass until 9–12 months after the burn,[11] and a delay in linear growth for 2 years after injury.[10] We speculate that the overall rate of catabolism in our group was lower than that in the patients with thermal injury, which resulted in faster recovery.

Identifying risk factors for poor nutritional status, we found different factors per age group. In general, the length of stay appeared to be the factor with the most negative effect on the course of the SD-scores over time. Meritt and Suskind[4] also found an association between prolonged hospitalisation and low anthropometric scores. The ICU-stay affected neonates (preterm and term) the most, which can be explained by the higher metabolic rate and energy requirement per kg body weight and the higher protein turnover compared to older children. These factors together will lead to a higher rate of catabolism in situations of critical illness and suboptimal nutritional support.[31–33] Furthermore, neonates are in a period of rapid growth in which it is crucial to consume the optimal amount of calories and protein.

Another important factor with a negative influence on recovery was a child's previous health status. The children in our study group with a history of disease or associated anomalies showed a high prevalence of malnutrition upon admission and during follow up. Andrassy et al.,[34] in evaluating the nutritional status of patients operated for oesophageal atresia in a long-term follow-up study, also found that children with a history of associated anomalies or illnesses frequently demonstrated the most severe depletions.

A limitation of nutritional assessment studies is the choice of reference standards for growth parameters. For children with a post-conceptual age <41 weeks we used growth charts that take differences in gestational age into account,[26] but we realise that it might not be fully appropriate to use intra-uterine growth data after birth.

Furthermore, the use of universal growth standards for the entire group might not be appropriate in view of the differences in growth patterns and growth velocity of different ethnic groups[35] and children with a history of disease, congenital anomalies or chromosome disorder. As every child, irrespective of ethnicity or underlying disease, will follow a certain individual growth curve, using the same standards for different groups will only have minor influence on the change in scores associated with longitudinal data.

The predicting factors we evaluated are not fully explanatory. The most important predisposing factor for the development or persistence of a negative nutritional status during ICU-stay is probably the inadequate intake of nutrients as a result of underprescribing or interruption of feeding.[36–38] Therefore, the roles of cumulative energy and protein deficits as well as type of feeding during ICU-stay in relation to growth parameters during follow-up need further investigation. Our study, for that matter, was merely of an observational nature, and only intended to quantify the malnutrition rate in a mixed population of children admitted to an ICU, including almost all admitted patients.

It was the epidemiological approach and mixed study population that made us choose anthropometric parameters to define the nutritional status of critically ill children. We are aware, however, that newer techniques, i.e. BIA and DEXA, have been applied in other populations such as children with inflammatory bowel disease (IBD) or cystic fibrosis (CF). However, in view of the impracticality of these methods and the lack of reference values for the younger age groups, we feel that they are still of limited value in the ICU setting with its heterogeneous set of patients. Furthermore, biochemical assessment, besides its disputable usefulness, would not have been routinely possible during follow-up visits. In other epidemiologically based studies that estimate the prevalence of malnutrition in hospital populations, anthropometric

criteria were used as well.[39–42] Nevertheless, we are aware that anthropometric methods have limitations in critically ill children, who frequently show oedema, water imbalance and renal, circulatory and hepatic problems. The presence of oedema upon admission will lead to an overestimation of SD-scores. The decrease in SD-scores seen at discharge will be influenced by the disappearance of the oedema and may, therefore, seem stronger than it really is. Even so, because we also found a decline in SD-scores between admission and 6 weeks after discharge and a return to admission levels at 6 months, we believe that our results hold up.

We conclude that although the long-term outcome in terms of nutritional status is relatively good for the majority of children discharged from the pediatric or neonatal intensive care unit, there remains a considerable proportion who are malnourished and need more attention during ICU-stay. The risk of developing malnutrition during a child's stay at the intensive care unit can only be minimised by starting standardised nutritional assessment upon admission, which should enable to identify children at higher risk and optimise their nutritional support.

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